Quantifying the human influence on the intensity of extreme 1- and 5-day precipitation amounts at global, continental, and regional scales

Qiaohong Sun¹, Francis Zwiers¹,², Xuebin Zhang³, and Jun Yan⁴
¹University of Victoria, Pacific Climate Impacts Consortium, Canada (sunqh@uvic.ca)
²Nanjing University of Information Science and Technology, Nanjing, China
³Climate Research Division, Environment and Climate Change Canada, Toronto, Ontario M3H 5T4, Canada
⁴Department of Statistics, University of Connecticut, Storrs, CT

Previous detection and attribution analyses suggest that human-induced increases in greenhouse gases have contributed to observed changes in extreme precipitation. However, all previous detection and attribution studies of observed changes in extreme precipitation i) use station data that have been heavily processed via gridding, transformation, and spatial and temporal averaging or other dimension reduction approaches, as well as using climate models to estimate the responses to external forcing, ii) also use models to estimate the unforced natural variability of extreme precipitation. Both aspects reduce user confidence in detection and attribution results.

We use a novel detection and attribution analysis method that is applied directly to station data in the areas considered without prior processing and use climate models only to obtain estimates of the space-time pattern of extreme precipitation response to external forcing. We use records of the annual maximum one day (Rx1day) or five consecutive days (Rx5day) precipitation accumulations from 5,081 land-based stations spanning the period 1950-2014 with at least 45 years of coverage, including at least 3 years in the period 2010-2014. Expected responses to external forcings are estimated from ALL and NAT forcings simulations from large ensemble simulations performed with CanESM2 and from a multi-model ensemble that participated in phase 6 of the Coupled Model Intercomparison Project (CMIP6). Changes at these stations are evaluated by fitting non-stationary Generalized Extreme Value (GEV) distributions at individual stations to the logarithms of observed Rx1day and Rx5day values. Non-stationarity in the GEV distribution is permitted by using location parameters that are allowed to be linearly dependent on climate model-simulated responses in ln(Rx1day) and ln(Rx5day) to different forcings. We perform the detection and attribution analysis across different spatial scales, including the global, continental, and regional scales.

The influence of anthropogenic forcings on extreme precipitation is detected over the global land area, three continental regions (western Northern Hemisphere, western Eurasia, and eastern Eurasia), and many smaller IPCC regions, including C. North-America, E. Asia, E.C. Asia, E. Europe, E. North-America, N. Europe, and W. Siberia for Rx1day, and C. North-America, E. Europe, E. North-
America, N. Europe, Russian-Arctic, and W. Siberia for Rx5day. Consistency between our study and previous studies substantially increases confidence in detection and attribution findings concerning extreme precipitation. The attributed effects of anthropogenic forcing on extreme precipitation include substantially decreased waiting times between extreme annual maximum events in regions where anthropogenic influence has been detected and intensification of extreme precipitation that, at a global scale is consistent with the Clausius-Clapeyron rate of about 7% per 1°C of warming.